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Light and Lighting

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Principal Contents:

Ultra Violet Illumination

WHEN the war is over more will doubtless be heard of the possibilities of fluorescence and phosphorescence, two of the most marvellous processes known to the illuminating engineer, involving as they do a transformation of radiant energy from one wavelength to another, conversion of the invisible into visible form or changes in the colouration of light.

Readers will find elsewhere an account of the processes underlying ultra violet illumination and its effects (pp. 109—117).

The value of fluorescence as a new mode of analysis, in distinguishing the genuine from the spurious and revealing signs invisible by ordinary light, was familiar in pre-war days.

In the new fluorescent tubular lamps we have since had another striking instance of its possibilities.

In time to come the excitation of fluorescent substances by ultra violet illumination will surely play an important part in many fields of lighting, notably in decoration and display where fluorescence renders possible effects of contrasts in brightness and colour scarcely attainable by any other means.

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Built-up Panel Lighting

The design of built-up panel lighting was recently discussed in a paper before the Illuminating Engineering Society of Australia (New South Wales) by Mr. Brian A. Smith, who is associated with the Sydney County Council. Papers on architectural lighting are usually distinguished by pictures of striking installations, but there is apt to be a lack of definite information on design. The design of the "box" in which the units are housed behind the panel is not quite so simple as may appear, and the choice of the translucent material is another complexity. Mr. Smith's paper was helpful. After dealing with fundamental principles, he gave a considerable number of diagrams embodying constructive information. The influence of depth of reflector on degree of uniformity of brightness and lumen output was illustrated, the performances of different forms of translucent glass were discussed, and data on transmission and reflecting power were presented. Armed with such data a designer should be able to avoid such elementary pitfalls as spottiness due to uneven spacing or imperfect positioning of lamps behind diffusing material. But if the "tactics" of architectural lighting can be readily mastered the "strategy" is, we are inclined to suspect, elusive. It is not easy to state precisely why some lighting schemes are satisfying whilst others create a vague impression of unrest. The desired effect is not obtained only by subdued brightness. One should eschew flatness and should bear in mind that some materials, such as figured glass, demand some high lights in order to be seen at their best. The main light should come from overhead, but one must avoid the "blaze" liable to result when high illuminations are attempted. We suspect that the feeling of rest and satisfaction which is the hallmark of successful architectural lighting is associated with the preservation of certain unities in regard to gradation of brightness, and the preservation of conditions resembling those obtained from the overhead sky in nature.

Colour Matching and Colour Discrimination

In the United States the Inter-Society Colour Council, which has functions somewhat similar to those of the Colour Group in this country, has been active in studying colour systems. There is also much interesting matter in the symposium of papers presented at the Annual Convention of the Illuminating Engineering Society (U.S.A.) last September. Readers in this country concerned with colour matching and artificial daylight should be particularly interested in the account by Miss Dorothy Nickerson ("Illuminating Engineering," March, 1941, p. 373) of the practical tests of materials examined by various forms of artificial daylight. A significant point made by the author is that the object to be served by an illuminant is twofold. The aim may be to find an illuminant under which colour differences, where they exist, can be detected with certainty. A somewhat different problem is to choose an illuminant by which colours are seen by an observer in the same relation to each other as under the illuminant to which he is accustomed (usually natural daylight). For the first purpose light of some special hue may answer best—for example, if samples of yellow are to be studied an illuminant rich in blue is best adapted to enable differences in hue to be detected, and vice versa. Sometimes a range of colour quality is desirable. In some dye houses specimens are examined by two selected illuminants, one having a colour temperature near that of horizon sunlight, the other approaching more nearly to the blue sky. Such an "abridged spectrophotometer" seems to work quite well in practice. Much of the practical work described in the paper is based upon the testing of selected "pairs," showing small colour differences, of material used in the cotton, tobacco, and coffee industries. A considerable variety of lamps yielding artificial daylight has been tested, and some experience has even been gained with the latest types of fluorescent daylight lamps. On the other hand, some regions have their own special fancies. In Argentina, for instance, a mercury-incandescent combination is being used in the cotton industry, and apparently it has also proved to have special fields of utility elsewhere.

Physical Society Colour Group

Forthcoming Meeting on September 24

A particularly interesting meeting of the Physical Society Colour Group has been arranged to take place at 2.30 p.m. on Wednesday, September 24, when three papers on "Whiteness" will be read. The meeting will be held at the Imperial College of Science and Technology (South Kensington).

Lighting experts are well aware that "whiteness" is a term that requires careful definition, and may be used with varying significance. The introductory paper by Mr. J. G. Holmes on "The Nature and Measurement of Whiteness" will review the subject both from the visual and colorimetric point of view, and such aspects as the sensitiveness of the eye to departures from white will be considered. Dr. V. G. W. Harrison, who is associated with the Printing and Allied Industries Association, will deal with "The Measurement of Near-Whites in the Paper Industry." The author will present spectro-photometric curves of typical pulps and papers, and will discuss the effect of adding dyes and the significance of such terms as "cream white," "blue white," etc., in the paper trade. The third paper by Mr. C. G. Heys-Hallett will consider the factors which affect the colour of a picture when a colour film is projected on a screen, especially the colour of the light source and of the screen used.

Ultra-Violet Illumination

by J. H. NELSON, Ph.D., A.R.C.S., A.Inst.P.

(Joseph Lucas Research Laboratories)

1. Introductory.
2. The Nature of Light and its Effect on the Eye.
3. The Production of Ultra-Violet Radiation.
4. Fluorescent and Phosphorescent Materials.
5. Illumination by Ultra-Violet Light.
6. Special Applications :—
   - (a) Laundry Marks.
   - (b) Instrument Lighting.
   - (c) Sign Lighting.
   - (d) Road Lighting.
   - (e) Decorative Effects.
7. Conclusion.

Introduction

The recent introduction of the "Black Lamp" has made possible the use of ultra-violet light for the production of decorative lighting, so that most people have seen some examples of ultra-violet illumination. To many these decorative effects have given the idea that other uses, often of a highly specialised nature, might be found for this form of lighting. The fact that the source of light is itself almost invisible, and that only those objects the designer intends to illuminate can be seen, makes the system particularly attractive to those trying to alleviate the gloom of the "Black-out."

The writer has often been asked for general or specialised data on the use and possibilities of ultra-violet illumination. As a rule the question is put by someone concerned with some definite problem, when it is relatively easy to select the appropriate information; but inquiries also come from those interested in a variety of problems, who want a general survey of the possibilities of ultra-violet light so that they can apply their knowledge to any new problems that may arise. For this purpose a very up-to-date text-book is needed, and as far as the writer is aware such a text-book does not exist.

This contribution makes no claim to give an authoritative exposition of the subject, but is written in the hope that it will give at least some picture of the problems and possibilities of ultra-violet light. To do this in a satisfactory manner it is necessary to describe in some detail what ultra-violet light is and how it compares with and differs from the ordinary light, with which we are all so familiar. Some account must also be given of the effect of ultra-violet light on the eye, and finally the fluorescent and phosphorescent effects which are used to obtain the illumination must be described.

After some account of the fundamentals of the subject possible uses can more easily be discussed, and limitations of a fundamental nature will become separated from those of a purely practical nature.

In most cases data given is representative; the real object is purely descriptive and not to provide accurate quantitative data, for which the reader must be referred to the technical departments of concerns responsible for the manufacture of the various articles described.

The Nature of Light and its Effect on the Eye.

Ordinary white light, such as we receive from the sun, is composed of a mixture of vibrations all having the same speed but differing in frequency. If by some means, for example, in the rainbow, these frequencies are separated, we obtain a series of very richly coloured lights. It is found that the colour corresponding to the lowest visible frequency is red, while, as the frequency increases, the colour changes through yellow and green to blue, and finally to violet, the highest visible frequency. Beyond the limits of this visible spectrum, as it is termed, we have the infra-red, of lower frequency, which we can best detect by its heating effect, and the ultra-violet, of higher frequency, which we can detect by several physical means, of which probably the most familiar is sunburn.

It is usual to refer to the various frequencies of light in terms of their wave-lengths; it is, however, more convenient to consider the energy associated with the frequency of each vibration. In order to explain the various amounts of energy available at each part of the spectrum it has been found necessary to imagine the energy emitted in discreet packets each associated with one particular frequency. These "quanta," as they are termed, are found to vary in energy content throughout the spectrum, and it is found that the quantum at any particular frequency is directly proportional to that frequency. Thus, a single quantum of violet light, i.e., the smallest obtainable amount of violet light, would contain nearly twice as much energy as a single quantum of red light. This fact is of fundamental importance in understanding the principles involved in ultra-violet illumination, as in using ultra-violet light we start with a high-frequency, large quantum, to which the eye is relatively insensitive, and then, at the point we wish to see, arrange a change of frequency so that the eye is sensitive to the new frequency. Now, as light is emitted as a series of quanta, this change of frequency will consist of taking an ultra-violet quantum and changing it into a quantum of visible light, which will have a lower energy content. Energy is therefore released in the process, and the material causing the change is not called upon to supply any energy, but will, in fact, be raised in temperature an infinitesimal amount by the excess energy. If, however, we took an infra-red quantum, which has a lower energy content than the visible light quanta, the change would not be possible, unless some method was found for supplying the difference in energy between the initial and final quanta. No direct method exists for doing this, and the only indirect method is very complicated. We may, therefore, accept as a fundamental rule that a quantum of light energy can only be changed into another quantum if the frequency of the second quantum is lower than that of the first. (This is really an expression of the second Law of Thermodynamics and applies to this case of quantum physics, providing statistical results are considered.) The mechanism of these changes will be considered when we discuss fluorescent and phosphorescent materials.

We have already noted that radiations of different frequencies have different energy quanta and different effects on the eye. Before describing the effects on the eye in more detail we will note some further differences in the physical behaviour of the various frequencies.

As most measurements are given in terms of wave-lengths these will now be used, and it must be remembered that a long wavelength corresponds to a low frequency and vice versa. The wavelength of light is very small and is conveniently measured in microns (10^{-6} metre $= 1\ \mu$). Thus the wavelength of sodium yellow light is $0.5896\ \mu$, or about half a thousandth of a millimetre. The accompanying table gives an indication of the properties of various wave-lengths.

It will be noticed from Table I. that as the wave-length gets shorter more substances become opaque to the radiation, until below $0.12\ \mu$ almost everything is opaque and the radiation can only be studied in a vacuum. Below this the phenomenon of transparency disappears, and all substances absorb radiation approximately in proportion to their densities. The transparency of many substances also disappears as the wavelength increases in the infra-red.

At present we are mainly concerned with the visible and near ultra-violet radiations, to both of which glass is transparent. The lens of the eye

absorbs the near ultra-violet strongly, thus making it almost invisible, while glass is opaque to the ultra-violet producing erythemal effects. The use, therefore, of ultra-violet light transmitted by glass is perfectly safe.

The most important case of transparency from the point of view of ultra-violet illumination is the

TABLE I.
Properties of Various Wavelengths of Light.

Wavelength (μ).		Remarks.
1.0	Infra-red.	Just detected by photo-cells.
0.8	"	Just visible to the human eye.
0.7	Red.	Practical limit to visible spectrum.
0.6	Orange.	Sodium yellow line 0.5896 μ. Mercury yellow line 0.578 μ.
0.55	Green.	Maximum visibility for the human eye.
0.5	Blue-green.	Mercury green line 0.536 μ.
0.45	Blue.	
0.40	Violet.	Practical limit to visible spectrum. Lens of eye becomes nearly opaque.
0.35	Ultra-Violet.	0.365 μ Mercury ultra-violet line. Just visible to the human eye from an intense source.
0.30	Glass becomes opaque. Cornea of the eye becomes opaque. Appreciable erythemal effects begin.	
0.2537	Mercury ultra-violet line. Radiation used in radio-therapy.	
0.20	Air, Quartz, and Gelatine become opaque.	
0.12	Fluorite becomes opaque.	
0.07	Neon ultra-violet line.	

special filter glass known as Wood's glass. This is very nearly opaque between 0.40 μ and 0.70 μ, while at 0.36 μ it transmits over 80% of the incident energy, becoming opaque again at about 0.30 μ. In the infra-red, too, there is some transmission reaching about 33% at 0.77 μ. This type of glass is of extreme importance in ultra-violet illumination, being used in every source of near ultra-violet, and will be referred to in more detail later.

The reflecting properties of materials also change with wavelength, for example, silver, which reflects so well in the infra-red and visible, reflects very poorly in wavelengths around 0.30 μ. For these wavelengths aluminium is about the most suitable material. Thus if a reflector is required for ultra-violet not transmitted by glass silver should not be used, and aluminium is the best material. Chromium plate is also sometimes used, and its ease of cleaning seems to justify its use in certain cases. For the glass-transmitted ultra-violet silver is generally the most suitable. The poor reflectivity near 0.30 μ is not of great importance, as in practice very little energy is available in this region.

Beside straightforward losses due to opacity and poor reflectivity, radiant energy may be lost due to scattering by impurities in the medium through which it is passing, or even by the molecules of the medium. This phenomenon also depends upon the wavelength. Most of us are familiar with the amazing clarity of long distance photographs taken with infra-red radiation. If the scattering particles in the medium are of the same order of size as the wavelength of the radiation, it is found that the shorter the wavelength the more the radiation is scattered. Under ordinary atmospheric conditions this effect may be quite marked. Many amateur photographers know the improvement obtained by the use of a yellow filter for distant views.

The effects of scatter in regard to illumination are two-fold, firstly, the object to be illuminated receives less light from the source and the eye receives less light from the object due to light "lost in transit," and, secondly, the eye receives unwanted light which casts a haze round the object. In the case of ordinary lights in a mist, or a searchlight in fairly clear weather, the light scattered into the observer's eye is much more serious than the loss in transmission. In the case of ultra-violet radiation the scatter is even more serious than in the case of ordinary light, but only the transmission is reduced, as the radiation scattered into the observer's eye is in any case invisible. Thus while back-scatter from the source produces no haze, the actual loss of energy is much greater than for visible light, being, in fact, about five times as great.

The effect of light on the human eye merits some attention if the problems involved in ultra-violet illumination are to be readily understood. In Table I. it was shown how the visibility of different radiations varies with their wavelengths, and how, in the visible spectrum the wavelength determines the colour sensation received. Measurements have been taken of the response of the eye to different wavelengths, and a curve can be drawn showing the relative response to energy at different wavelengths. This is known as the "Visibility curve." For purposes of illumination and photometry a standard curve has been agreed on by the C.I.E. (See Fig. 1). The maximum response is found in the green part of the spectrum at 0.555 μ, and on each side of this the response falls until the practical limits of the spectrum, situated at about 0.40 μ and 0.70 μ in the violet and red ends of the spectrum respectively, are reached. At these radiations there is no sudden stopping of the response. Measurements show that in the infra-red there is a steady fall in sensitivity up to 1.0 μ, beyond which the writer is unaware of any measurements. On the ultra-violet side the same steady fall in sensitivity is found beyond 0.40 μ. This diminution has been shown to be due to the lens, but at just above 0.30 μ there is a sharp fall in sensitivity due to the complete opacity of the cornea. The important point to realise in using ultra-violet radiation above 0.30 μ is that the invisibility is only relative, and the actual source of light will always be visible to some extent, though the ultra-violet light scattered by the air or by objects on which it is incident, will in general be below the threshold of visibility.

It has been explained that the colour sensation produced by radiation is a function of the wavelength. We can, with advantage, expand the table given previously so as to have a fairly complete picture of the spectrum colours and their corresponding

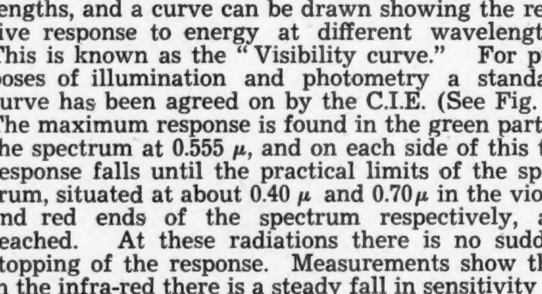


Fig. 1. Visibility curve for the normal human eye.

wavelengths (see Table II.). These colours are far richer than those met with in ordinary life, the latter being always the result of a mixture of wavelengths giving a "mean colour."

TABLE II.
Colours corresponding to Ranges of Wavelength throughout the Visible Spectrum.

Spectrum colour.	Corresponding wavelength (μ)
Red	0.64 and above.
Orange	0.60 — 0.64
Yellow	0.58 — 0.60
Yellow-green	0.55 — 0.58
Green	0.51 — 0.55
Blue-green	0.47 — 0.51
Blue	0.44 — 0.47
Violet	0.39 — 0.44
Blue	Below 0.39

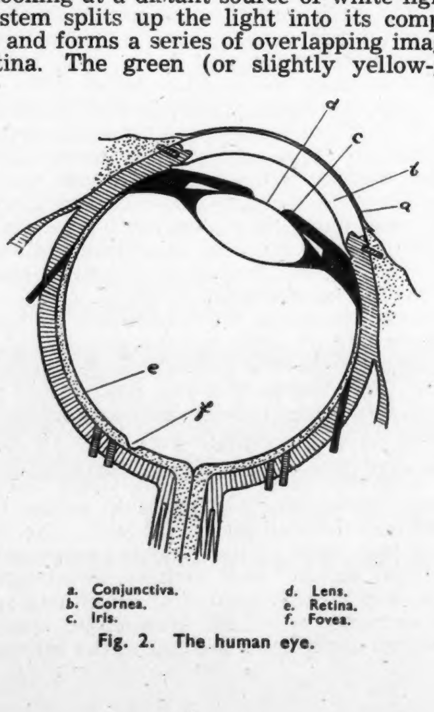
From the above table it is seen that for wavelengths below 0.39μ the colour sensations is blue. This region is near to the ultra-violet, and the eye is very sensitive. This is also confirmed by observers who have had the lens of their eye removed. Since it is the lens which mainly absorbs these radiations, such observers can see this region of the spectrum very much better, the luminosity of $0.365\ \mu$ being about 1,000 times the normal. The explanation for this reversal in the colour change is not clear, but may lie in the process of colour vision, which is supposed to involve some triple mechanism by which each wavelength effects differing amounts of three fundamental responses.

The Optic Media

Owing to the somewhat peculiar effects which occur when the eye is exposed to near ultra-violet radiation, it is worth while examining the optical system of the eye in some detail.

The most important optical parts of the eye are the outer surface of the cornea and the lens (Fig. 2). These together constitute a powerful optical system, which forms an image of a distant object on the surface of the retina—the sensitive layer associated with the optic nerve in conveying the picture of the outside world to the brain centres. When we look at an object we turn the eye so that the image of the object under examination falls on the fovea, which is the centre of greatest acuity of vision.

The optical system of the eye is not an achromatic one. Therefore radiations of different colours are not all treated exactly on the same basis. When the eye is looking at a distant source of white light, the lens system splits up the light into its component colours and forms a series of overlapping images on the retina. The green (or slightly yellow-green) image is most nearly correctly focused, while the yellow, orange and red are progressively larger owing to the lens system being too weak. On the other hand the blue-green and blue images have actually been formed in front of the retina, and the patch of light on the retina is larger than the correctly focused one, because the lens system is too powerful. The normal eye is therefore hypermetropic, or "long sighted," to red light and myopic, or "short sighted," to blue light. When we go to the ultra-violet we find that this short-sightedness is increased so that as to become very noticeable. In the ordinary way it is possible to suppress the unwanted images and we see things perfectly clearly. The writer finds, however, that an additional correction of —1.5 to —2.0 dioptres is necessary to enable him to focus the mercury ultra-violet line at $0.365\ \mu$.



a. Conjunctiva.
b. Cornea.
c. Iris.
d. Lens.
e. Retina.
f. Fovea.

Fig. 2. The human eye.

In practice this myopia to ultra-violet is aggravated by the fact that in most cases the source also emits some infra-red radiation, to which the eye is, of course, hypermetropic. Now when we look at near things we make the lens of the eye more powerful and thus produce a state of artificial myopia. It is therefore possible to bring the infra-red into focus by accommodation, but at the some time the ultra-violet focus is made worse. This action is almost entirely involuntary, and it is only by bringing the source within a few inches of the eyes that it is possible to focus the ultra-violet at the expense of the infra-red. The first thing that becomes obvious when we see an ultra-violet source in the open is thus a large blue disc at the centre of which is a red spot due to the correctly focused infra-red. This infra-red radiation is very troublesome if the source has to be really invisible, since it is actually very much easier to see than the ultra-violet.

We have noted previously that the radiation below $0.40\ \mu$ is strongly absorbed by the lens of the eye. In actual fact the lens does somewhat more as it fluoresces and thus emits ordinary visible light. Consequently when the eye is near an intense source of ultra-violet this fluorescence in the lens creates the sensation of an apparently uniform haze over the whole field of view.

The relative importance of the out-of-focus image of the source and the haze caused by fluorescence is found to differ with different observers. This is probably due to the fact that the transparency of the lens varies with age. A young child can actually see further into the ultra-violet than the adult, and it is known that the lens is hardening continuously throughout one's life. Now when the lens is very transparent it is obvious that the out-of-focus image will be of more importance than the haze, and conversely when the absorption is higher the haze will gain in importance. The haze will thus be more annoying as the age of the observer increases, and in designing equipment for use by a particular age-group the age of the users might well receive some consideration if either effects are likely to be troublesome. It is, however, unlikely that the haze due to fluorescence will ever be so strong as to be visible when the optical image is invisible. The writer finds that he can always see the optical image long before the haze, the haze only being noticeable when the ultra-violet radiation is intense.

It has been stated previously that the radiation immediately below 0.40 produces no injurious erythemal effects, and as a rule those radiations transmitted by ordinary glass are harmless. If, however, the wavelength is reduced below this wavelength, say to 0.28μ, there is no sensation of light and no fluorescence. The radiation is then absorbed in the outer layers of the cornea, and the outer skin of the eye, the conjunctiva, is irritated causing considerable pain and inflammation. No permanent injury results in most cases. Nevertheless, conjunctivitis is sufficiently unpleasant to make one guard against a second attack. Apart from the practical

difficulties of using these radiations it would be necessary to take care to guard the users if it were possible. The attraction of complete invisibility is great, and the erythemal effects are not immediate and could not be used to detect the radiation. Suitable goggles could, of course, be worn for protection, as they are worn when receiving ultra-violet treatment. Similar goggles can also be obtained to eliminate the annoying effects of the near ultra-violet.

The Production of Ultra-Violet Radiation.

In principle the production of ultra-violet radiation is exactly the same as the production of ordinary light. It is present in sunlight and also in electric light. The essential problem is not so much the production of the ultra-violet as the efficient elimination of the visible light, and the efficient production of ultra-violet energy itself is in general a secondary problem.

The elimination of the visible light has been made possible by the introduction of a filter glass, known generally as Wood's glass, the transmission curve for which has a deep opaque band extending throughout the whole range of the normal visible spectrum.

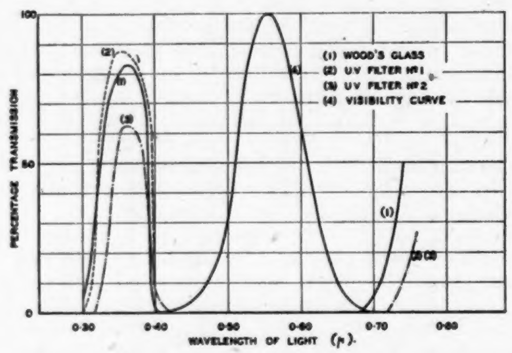


Fig. 3. Transmission curves for ultra-violet filters.

A typical transmission curve is shown in Fig. 3, from which it appears that while the transmission between 0.41μ and 0.68μ is negligible, the near ultra-violet and infra-red radiations are transmitted fairly freely.

As we have seen, the visibility curve of the eye does not terminate sharply at what are normally termed the limits of the visible spectrum. In consequence the radiations transmitted by Wood's glass are not invisible. Recently glasses have been developed, which yield considerably better transmission curves in the near infra-red region. One of these (Fig. 3) glasses will give as much as 86 per cent. transmission at $\lambda = 0.36\mu$, but is somewhat thick. The other glass gives only 63 per cent. for approximately the same extinction of visible light, but can easily be blown into bulbs.

The Tungsten Filament Lamp.

The simplest source of ultra-violet radiation is the ordinary tungsten filament, used in conjunction with a Wood's glass filter. In this case the maximum of the transmitted ultra-violet energy occurs at about 0.38μ(Fig. 4). When it is remembered that the energy available at this wavelength is only about one-twentieth of that available at the point of maximum energy for a temperature of 3,000 degrees K, it can be seen that the efficiency is not very high. In practice the filament is run at as high a temperature as possible, and in this way the maximum proportion of ultra-violet energy to heat energy is obtained. The excessive heat, produced, however, makes the tungsten filament unsuitable for the production of large quantities of ultra-violet.

When only a small output is required the simplicity of the tungsten lamp is a definite advantage.

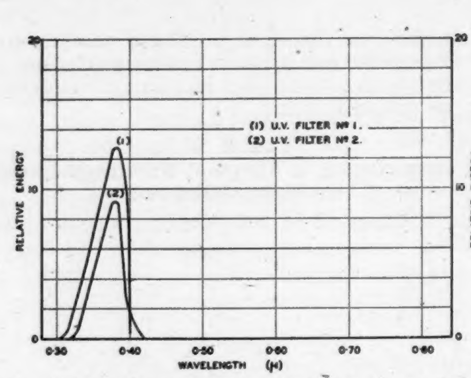


Fig. 4. Ultra-violet energy transmitted by ultra-violet filters (tungsten filament at 3,000° K).

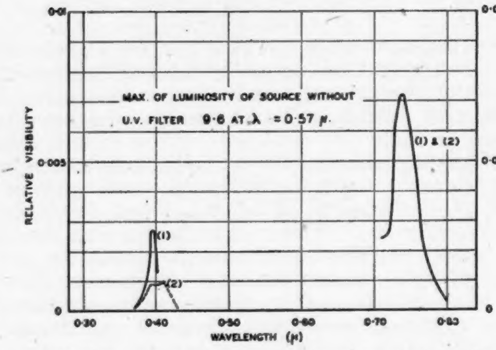


Fig. 5. Visibility of radiation transmitted by ultra-violet filters.

Curves are presented showing the performance of lamps with various glasses (see Fig. 4 and Fig. 5). If a fairly compact source is necessary the wattage must be limited. In the case of the ordinary car headlamp, for instance, the convenient limit is 36 watts, because if 60 watts are used the glass becomes too hot in all but the larger lamps.

The Mercury Vapour Lamp.

A much more efficient source of ultra-violet energy is the mercury vapour lamp. When only small amounts of energy are required the low pressure type with a glass tube may be used. This would supply a source of fairly large dimensions and the filter could be made the envelope enclosing the arc. As far as the writer is aware this has not been done, as lamps of this type are principally used for laboratory work and the demand is small. The mercury tube is usually bent into the form of a "U" and totally enclosed in a sheet metal box, having a suitable Wood's glass window.

For larger amounts of energy and when a source of convenient size for use in a reflecting system, the high pressure type of lamp is used. The most familiar example of this is the 125 watt black lamp. In this lamp the mercury arc is confined in a small quartz tube about 1½ in. long and ⅜ in. diam., this tube being totally enclosed in a Wood's glass jacket of the conventional house-lighting bulb shape and being about 7 in. in overall length.

For some purposes the dimensions of this lamp may prove unduly large and the 40 watt size, having a quartz tube about ½ in. long, is much more convenient. The efficiency of this lamp is not so high, and it is only made with a clear glass jacket; it can, however, be more easily focused in small projection units.

For a given output of ultra-violet energy the mercury vapour lamp is superior to the tungsten lamp in that the visibility is far less. This is due to the fact that most of the radiant energy is concentrated into certain well defined wavelengths, and there is only a small amount of continuous spectrum in the extreme red. This continuous spectrum is transmitted in the same manner as the corresponding

part of the spectrum for the tungsten filament lamp, but is very much less intense. In the violet region the mercury line at 0.4047 μ will be transmitted to some extent, but there is nothing between this line and the principal ultra-violet line at 0.365 μ, which is near the point of maximum transmission for Wood's glass. The visibility of the 0.3650 μ line is unavoidable, but is less than one-tenth of the visibility of the ultra-volet energy transmitted from the tungsten lamp.

The Argon Lamp.

The argon lamp provides a high efficiency source of ultra-violet radiation of small output. The efficiency in this case is even better than for the mercury lamp both from the point of view of ultra-violet energy obtained for a given input, and in regard to the visibility of the source. Outputs are, however, limited to a few watts, and as the discharge is a low pressure one the source of brightness is not high. The applications of this lamp would be substantially similar to those of the tungsten lamp. The choice thus lies between two drawbacks, the high voltage supply necessary for the argon lamp and the heat and visibility given by the tungsten lamp.

The Two-stage Mercury Lamp.

A recent development designed to replace the argon lamp in aircraft instrument illumination is the two-stage mercury lamp. In this lamp the original source of radiant energy is a low-pressure mercury discharge tube. This gives some radiation in the near ultra-violet, but a large amount of energy is radiated in the resonance line at 0.2537 μ. This energy is not efficient in exciting ordinary fluorescent materials, and is dangerous because of the erythemal effects it will cause. It can, however, be converted into visible and near ultra-violet energy by certain types of fluorescent materials. Thus in this lamp, besides the ordinary near ultra-violet lines, we have a continuous distribution in the near ultra-violet provided by fluorescence excited by the far ultra-violet. This fluorescent lamp is enclosed behind a suitable filter to eliminate the visible light and provides a very efficient low wattage source. The lamp is available in the United States in 4-and 6-watt sizes, and is claimed to be superior to the argon lamp both in output and visibility.

Fluorescent and Phosphorescent Materials.

To make use of the ultra-violet radiation we have produced, we are dependent upon a set of substances that have the property of absorbing the ultra-violet radiation and re-emitting the energy in the form of visible light. These substances are divided into two types, fluorescent substances, which re-radiate the energy immediately or without an appreciable time lag, and phosphorescent materials which absorb the ultra-violet radiation and re-radiate the visible energy for some considerable time after the exciting source has been turned off. Most materials, organic materials especially, exhibit the property of fluorescence in some degree. The metals are exceptions and, as would be expected, show no sign of luminescence.

In practice we make a further sub-division in the luminescent materials according to the range of wavelengths in the ultra-violet giving the best excitation. The materials used in connection with ultra-violet illumination have to be most efficiently excited by the near ultra-violet, say between 0.36 μ and 0.39 μ, and these materials are quite distinct from those excited by the short wavelengths, as for instance the 0.2537 μ line. The two classes of substance fall roughly into those which are excited by near and glass-passing ultra-violet, and those which are excited only by short wave ultra-violet.

Both classes of materials have received considerable attention in various industrial laboratories. Those excited by the near ultra-violet have been developed to give various colours on excitation. The colour on excitation is often quite different from the colour of the materials in ordinary light. The short wave materials have been developed to produce a variety of intense colours, and in particular to radiate an intense daylight white. These developments are associated with the new mercury fluorescent lighting, in which the luminescent powder is placed on the inside of the glass tube containing the arc and is excited by the 0.2537 μ line, almost all the luminous intensity being derived from the fluorescence. Most of these materials have a fairly sharp decay after the exciting source is switched off, but the decay is sufficiently long to prevent the annoying flicker usually associated with discharge lighting.

The brightness of the near ultra-violet materials varies over quite a wide range of different colours. The greens are generally the brightest and the yellows and blues (the latter rather pale), follow. The reds are generally not very intense. As a rule, materials which are slightly phosphorescent are brighter than fluorescent materials. This is due to the fact that in many cases it is necessary to " kill " the phosphorescence in order to obtain a material which exhibits only fluorescence.

Phosphorescent materials having a medium decay time can be obtained only in a somewhat restricted range of colours, and those having a really long decay time only in yellow-green and blue-green. A salt yielding the latter colour has proved the best that the writer has seen for long decay combined with high brightness.

One of the materials which can easily be used to make a fluorescent wash is Anthracene. This gives a very pale green fluorescence and can be used as a paint with water-glass as a base. The ordinary commercial Anthracene provides a very cheap material, but is not very efficient. If the Anthracene is further recrystallised the efficiency improves steadily and the colour becomes bluer.

Zinc Sulphide fluoresces very strongly and is perhaps the material best known for exhibiting fluorescence. It has, however, to be specially prepared, and the method of preparation determines its effectiveness. Minute traces of an impurity, known as an Activator, are used to control the colour and nature of the luminescence.

A plastic sheet material is often used in displays. This material is similiar in form to celluloid, and is available in a range of colours. The brightness is considerably higher than anthracene, the brightest colour being a green. This green material is interesting as it is almost completely transparent to wavelengths down to about 0.45 μ. Objects can therefore be seen through the material without apparent loss of definition in ordinary daylight.

Fluorescent and phosphorescent materials may also be incorporated in paints, attention being paid to the choice of the base so that it does not impair the efficiency of the material. Fluorescent paint can be obtained in a base similar to that used as road line paint, and so is very hard wearing. Some deterioration of the material owing to exposure is to be expected, especially to bright sunshine. When the paint is subject to heavy wear, as for example on stone steps, the deterioration of the material is not so noticeable, and the life of the paint is comparable with ordinary white road paint.

Phosphorescent paints are also available, but phosphorescent enamel is more used. Enamel signs in a variety of forms are obtainable. These stand up very well to exposure, although it is advisable to protect them from direct sunlight. In some cases even prolonged exposure to direct sunlight will cause only a small amount of deterioration; the material appears to reach a steady state after a small initial fall in effectiveness.

Fluorescent materials are not limited to use in the form of paints, the same powder as is used in a paint can be incorporated in a moulding material or a

chalk, and the same, of course, applies to phosphorescent materials. Finally, certain dyes are known to fluoresce, which gives one fluorescent cloth or tape.

From the above it can be seen that we can look upon fluorescence or phosphorescence as just another colour, which can of course occur in a very large number of ways. Such being the case it is not necessary to enumerate the possible methods of use, except in so far as they illustrate a particular principle.

So far we have had two examples of how fluorescent materials may be used in connection with ultra-violet radiation. The first and most obvious is to reveal the presence of the object which has been treated. The second involves the production of light to illuminate another object. This light given off in the second case may be either visible light or, as in the case of the aircraft instrument lighting, ultra-violet.

An interesting modification of the first example exists in the use of a cat's-eye reflector. In this the fluorescent material is placed in the focal plane of a lens and shielded so that it is only visible through the lens. This unit will act in exactly the same way as the ordinary cat's-eye reflector which returns light incident on it to within a small angle of the source from which it came. Such a device is advantageous for two reasons: firstly, the area of fluorescent paint needed for visibility is so much less than with a plane disc and, secondly, the object is only rendered visible to observers when near the source of ultra-violet radiation, thus tending to increase the secrecy possible. An instance of the efficiency of this cat's-eye device is worth mention. The mirror backing of one of the moulded glass reflector units, familiar on road signs, was replaced by fluorescent powder. The diameter of this unit is about an inch, and the light emitted in the direction of the ultra-volet source was found to be equivalent to what would have been available from a square foot of fluorescent material if emitted naturally in all directions. Most cat's eyes have been designed to give the minimum spread practicable in the return beam. Obviously the designer may choose any spread he likes; for example, he may cause a fan of light to be given off by using cylindrical lenses or a limited cone by suitable choice of the lens curvature.

So far we have used the fluorescent material to illuminate our object or to render the object self-luminous. A further alternative exists, namely, that of rendering the object visible by silhouette. For this purpose the dyes are most suitable. A typical example of the use of such a device is a piece of paper treated with a fluorescent dye, then any pencil or ink line drawn on the paper will show up silhouetted against the bright background afforded. This method may of course be used instead of or in conjunction with a fluorescent ink.

Illumination by Ultra-violet Light.

Until recently the use of ultra-violet illumination was confined to the specialist in the laboratory. Probably the most important explanation was the lack of suitable sources of radiation. In addition, it is only recently that there has been any real extensive range of colours of high brightness available in fluorescent materials. The laboratory uses are, in general, not examples of illumination, but are rather processes of analysis. For instance, the detection of a fluorescent component in a mixture by irradiation is hardly an illumination problem in the ordinary sense of the word. The ultra-violet microscope is again something different, as we are using quite a different property of radiation, and the result is generally recorded photographically.

The provision of the intense ultra-violet source given by the high-pressure mercury vapour lamp was in reality a fortunate accident. This lamp was actually developed in the search for greater efficiency in the production of visible light.

The earliest popular use for ultra-violet illumination was display lighting with the mercury vapour "black lamp." Sheets of fluorescent celluloid, which could be cut and made up to give many different effects, were prepared and irradiated, the artificial flowers being among the most attractive. For display purposes and the production of effects, either in the shop window or on the stage, the possibilities of ultra-violet illumination are endless. These uses are, however, entirely ornamental and efficiency does not need more than passing consideration.

When ultra-violet radiation is to provide utility illumination, the efficiency is of prime importance and the comparison with ordinary white light must always be borne in mind. The attractiveness of the system tends to create a desire to use it for purposes for which ordinary white light would do quite as well; in such cases it is, of course, wasteful, as white light is always more efficient for providing a given level of illumination at any one place. The real test of whether ultra-violet illumination should be used or no is whether the stray light associated with the white light source will be harmful. If it can be shown that this stray light is prejudicial then a case for the use of ultra-violet may exist. At the same time it must always be remembered that there is some stray light when an ultra-violet illumination system is used, and so the stray light problem cannot always be solved by changing from white light to ultra-violet. With visible light the stray light will come from the source, the atmosphere surrounding it, and all objects illuminated by the source, reflected images.

The fact that the ultra-violet source is not invisible is one that requires emphasising very strongly, especially to those whose experience of ultra-violet illumination is limited to a few well-planned installations, in which the source is so placed and shielded as to be quite inconspicuous if not invisible.

The necessity for shielding the ultra-violet source effectively very often makes the use of ultra-violet inadvisable. To take a practical example, suppose that instead of using a number of small visible lights in a region it is proposed to floodlight the scena with ultra-violet light. If the whole scena is to be invisible from the air and the ground visibility is to be limited by the visibility of the fluorescent markings, or the local lights it is wished to replace, then the ultra-violet source must, in general, be mounted above the scene, and the height at which mounting is possible will determine whether the simplicity of installation of one or two ultra-violet floodlights is an advantage over the more cumbersome installation of a number of position lights. Each case must, of course, be decided by its own particular conditions. All that it is possible to do here is to stress the fact that in rendering objects self-luminous the ultra-violet source is causing unwanted stray light, which must always be examined in order to see whether it is harmful to the purpose of the installation.

Applications of Ultra-violet Light.

So far ultra-violet illumination and its properties have been discussed as a general problem, except where an example has been used to illustrate any particular point. Such a general discussion is essential for the understanding of any subject, but is perhaps specially necessary in this case, because of the highly-specialised uses to which ultra-violet illumination is put.

One interesting example of the use of ultra-violet illumination is in providing an invisible and really practicable laundry mark. Most people have at one time or another been exasperated by the habit laundries have of returning handkerchiefs and shirts covered with blotches of ink intended to identify the article in question. In some cases matters are very slightly improved by the use of a small woven tape

sewn on, but even this is not pleasing when, after a few visits to the laundry, one's handkerchiefs come back with "792D" on each corner. The latest device, which will be hailed by many sufferers, consists in stencilling the appropriate marking with an invisible fluorescent dye, and arranging that sorting is done under ultra-violet lamps. The advantages of this system are obvious; the marks can be of reasonable size, inch letters being used, repeated marking will generally be unnecessary, but will not worry the owner of the much-marked article, and, finally, the use of a large mark will tend to reduce mistakes in sorting to the minimum. This example is interesting because, in spite of its specialised nature, it shows that ultra-violet illumination can have a very practical use in everyday life.

Instrument Lighting.

The use of ultra-violet illumination for aircraft instruments has been referred to in describing the two-stage mercury vapour lamp. It is clear that this method of illuminating instruments is particularly suited to aircraft both in peace and war, since the pilot sees only the minimum of light and is not, therefore, distracted from what little he can see of the outside world. Instruments in power stations may also be illuminated by this method, but the high-power mercury vapour lamp would necessarily be used in this case. In both the above cases an interesting safety device is available. Phosphorescent paint having a fairly long period of phosphorescence is used, so that in the event of the power supply failing, the instruments will remain visible for a long time. In the case of aircraft the phosphorescent paint is often energised radioactively, and many pilots find it unnecessary to use any further energising.

Motor-car instruments have also been illuminated by ultra-violet. In this case a small tungsten filament run at a high temperature and enclosed in Wood's glass was used. This method of dashboard illumination, however, does not seem likely to become general, and for very sound reasons. In a car we cannot place the U.V. source where convenient, i.e., behind the driver's head, as the interior of a car has to be made to suit the eye of the purchaser rather than on strictly utilitarian lines, as in the case of an aeroplane cockpit. Hence we are forced to illuminate the instruments from a very short distance—as we should be, in any case, by the low power available—and the distribution of intensity over the instrument surface is in no way assisted by the use of ultra-violet illumination.

Sign Lighting

The facility it affords for maintaining some degree of brightness in the event of failure of the mains supply makes ultra-violet illumination very suitable for the lighting of A.R.P. signs, especially when it is possible to light a number of direction posts or obstructions from one central source. Such a system would seem to be most suitable for lighting the approaches to trench shelters near a factory, where a large number of people might have to evacuate quickly. In this case the ultra-violet system has a definite advantage over locally illuminated signs, in that obstructions, steps and the outline of any doorway can be picked out in phosphorescent paint. If such an installation is planned with care excellent results can be obtained without there being any question of danger due to observation from the air, but of course care must be taken that luminescent paint is not used indiscriminately, otherwise the installation will be just as dangerous as a poorly designed white light one.

Road Lighting

Those who have driven along one of the main roads, which have the edges and centre marked with little reflectors, will know how clearly these reflectors mark out the course of the road even when one is limited to a war-time masked headlamp. These little reflectors are so designed that they return a beam of light in the direction of the source illuminating them, so that they appear very bright to the man behind the headlamps, but can hardly be seen by someone to one side. This type of reflector can be made to work when illuminated with ultra-violet light, and arranged so that when a beam of invisible ultra-violet falls on it a narrow beam of visible light is returned towards the source.

If, therefore, we install a system of such reflectors along a road, a car equipped with an ultra-violet headlamp could be driven without any additional light. The provision of such a headlamp would not be a very great problem, in fact it would only mean replacing the peace-time bulb by one with a Wood's glass jacket.

At first sight, such a system has a great advantage for war-time driving in that it would permit driving in almost complete darkness at speeds comparable with peace time. There are, however, many disadvantages, which render the system only suitable for very special cases. The most obvious of these is that traffic is put on railway lines, and it is necessary to assume a clear path; every accidental obstruction would have to be marked. Pedestrians would have to have some form of luminescent marking. Bomb-craters which might arrive during the night would be a great danger. The number of reflectors necessary to cover all roads to make the system universal would be enormous, as would the job of installing them.

One rather interesting suggestion has been made, and that is that ultra-violet might provide some help if not a solution to the problem of driving in fog. The main problem in providing lights in fog is how to eliminate the annoying backscatter, and, of course, this is done completely by an ultra-violet system, as any backscatter would be of too low a brightness to be visible. We could therefore be certain that the only things illuminated by the source would be the reflectors, thus providing a definitely marked route. Against this there is the fact that ultra-violet radiation is scattered so much more severely than visible light that the loss of power along the beam would be about five times what would be expected from white light.

The same argument has been put forward for the use of an ultra-violet searchlight, but this suggestion has generally assumed the invisibility of the searchlight to the object being illuminated, and not always explained how the luminescent material is to be placed on the object. As means of identification such a searchlight would obviously be of value, but its range does not seem to be very great, and it would be very easily seen.

Decorative Effects

So far, the possible uses of ultra-violet have been strictly utilitarian. The fact that fluorescent and phosphorescent powders can be made in various colours should not be forgotten. The entrance-halls of many cinemas are now illuminated by ultra-violet light, and the skilful use of coloured sheets of a special form of celluloid provides many interesting effects. On the stage itself one may see an even more vivid display of colour, fluorescent dyes being used for drapery, which may be in one colour in ordinary light and in another under ultra-violet. A picture in rich colours can be painted in fluorescent salts, at least it is a picture under ultra-violet, but may appear just a plain board or even a picture of something else under ordinary light. The lightning artist may draw with many-coloured crayons, and if everything is in darkness the sketches will appear to come from nowhere. In fact, in the hands of the effects man ultra-violet illumination can provide both amusement and beauty.

Conclusion

No attempt has been made to write a treatise on ultra-violet illumination, but it is hoped that most of the peculiarities to be expected from ultra-violet light have been mentioned. The object has been to

dispel the notion that ultra-violet solves all problems, and at the same time squash the idea that it is only a pretty toy. The best way of doing the latter is to call attention to the new tubular fluorescent lighting, which, although very different from what has been discussed, is essentially a specialised development of ultra-violet illumination.

Possibly the stage use will be the most well known of the uses of ultra-violet light, but the "laundry-mark" use has obvious possibilities for industrial purposes.

The lighting of roads and shelters by ultra-violet is obviously only the "war paint," and other uses can be found for such a lighting system in war, but there is no need to imagine that its uses are entirely limited to A.R.P. and Blackout.

Electrical Association for Women

Sixteenth Annual Report

Although the war has naturally interfered with the normal activities of the Electrical Association for Women the report for the past year records a considerable amount of useful service. During this period Miss Caroline Haslett, the director, has acted as adviser on women's training to the Ministry of Labour. Canteen service has been one of the war activities of the Association. In 1940 the E.A.W. Mobile Canteen Service was inaugurated. Hospitals, Refugees, the Forces, the Anti-Aircraft and Balloon Barrage units, and the Civil Defence Personnel have all benefited from the efforts of branches. Funds have been collected for many special purposes, including the provision of special electrical apparatus. One effect of the war was to condense the Annual Conference into a one-day function on April 18, but there have been many instances of participation in conferences and co-operation with other bodies.

The Winter Blackout

The double daylight saving plan has given us such a long period of natural lighting that we are apt to forget the coming winter and the return of urgent blackout problems. It is to be hoped that factories throughout the country are making good use of the summer (with its unexpectedly tranquil conditions) to introduce scientific blackout methods, enabling maximum use of daylight to be made throughout the day. We are reminded of this problem by the receipt of a description of an unusually complete blackout installation with which the G.E.C. were associated. Originally, this factory was completely blacked out by boards fitted to the outside of all the North Lights and other windows. The new scheme is based on the removal of alternate opaque panels, which are mounted in a frame capable of lateral displacement. It is thus possible to have either two opaque panels, one above the other, in which case half the available daylight is admitted, or to shift the movable opaque panels into position over the free areas, so that a complete blackout is effected. Though simple in effect, the mechanism is somewhat elaborate. Each span of lights of 1,000 sq. ft. is operated by one $\frac{1}{4}$ h.p. motor, and 500 such motors have been installed. A special precaution, in order to render the operation of the controlling motors independent of the main electric supply, has been the installation of twenty 12-volt storage batteries, which are trickle-charged. The whole installation can be put into operation by merely pushing a button in the A.R.P. control room. Not every factory can afford such a complete scheme, saving 50 per cent. of daylight. But experience shows that the admission of even a small proportion of the total daylight available is well worth while, provided the light is well diffused and distributed.

The Heating of Factory and Office Lighting Fittings and their Connecting Leads

by H. G. TAYLOR, W. LETHERSICH and P. D. MORGAN

Summary of a Contribution to the B.E.A.M.A. JOURNAL, 48, pp. 11-15; 27-31; 41-44; 67-68.

An important factor to be considered in the satisfactory maintenance of any lighting installation is the operating temperature of the leads with which the fittings are wired. This problem has received considerable attention from the British Electrical and Allied Industries Research Association, and the results of the recent investigations are published in the first four monthly issues of the B.E.A.M.A. Journal for 1941.

Initial investigations by the B.E.A.I.R.A. were made into the problem some nine years ago, and the present report represents a survey of present fittings. It was found that in this interval some advances had been made in the design of fittings to meet this problem.

The general use of gas-filled lamps has often resulted in unduly high temperatures, and, as a result, the insulation is liable to deteriorate. This deterioration increases with the temperature of operation. It has been found by experience that a temperature of 50° Centigrade is the maximum safe temperature for ordinary rubber insulation. If this temperature is exceeded the rubber becomes brittle and on slight disturbance may crack off and expose bare conductors, with the chance of a short circuit.

The point of greatest danger is where the two wires come into contact, and in a B.C. holder this has been taken as ⅜ in. from the terminals. This dimension has also been adopted as the minimum dimension to be considered in both E.S. and G.E.S. lampholders.

All the results given in the B.E.A.I.R.A. report are in terms of temperature rise in Centigrade degrees. An ambient temperature of 32.2°C.* has been adopted. A small change in ambient temperature will very slightly influence radiation and convection losses, and thus the final operating temperature This effect, however, is very small, and for all practical purposes the final operating temperature may be taken as the sum of the temperature rise and the ambient temperature that occurs in normal practice.

Tests were conducted under standardised conditions in a draught-free enclosure. In order to corelate with representative practical conditions some tests were also made with windows open in an open room. Temperature rises of the insulation at the most vital parts were not reduced by more than 10 per cent. below the rise obtained in the enclosure.

Tests were also made under still conditions in an open room, and it was found that temperature rises were slightly higher than in the test enclosure. This may be explained in the following way. The ambient temperature in the open was slightly lower than in enclosure. The higher ambient temperature in the enclosure thus produced higher working temperatures and, in consequence, slightly higher convection and radiation losses. The convection loss for a given temperature difference increases slightly with the temperature, and the radiation loss increases as the difference of the fourth power of the two temperatures in absolute units that form this temperature difference. Thus, a greater loss of thermal energy at the higher ambient temperature in the enclosure will result in a slightly lower temperature rise than at the lower ambient in still air.

The results shown cover tests on representative fittings followed by a study of the methods of reducing the temperature rise. The application of these methods follows, together with a study of fittings of recent design.

The factory fittings considered include the smaller type with shade ring suspension, and the more normal medium type with E.S. and G.E.S. holders. Representative fittings employing a diffusing bowl are also considered.

The results obtained on existing factory fittings fall into two groups. One group consists of a complete range of fittings that have been designed with the objective of a low operating lead temperature. This objective has been achieved, and the results (Table IX) indicate a substantial reduction in operating temperature when compared with results obtained on somewhat similar factory fittings of the ordinary type (Table II.).

In the case of the smaller fittings of the latter type, i.e., small pendant reflectors with shade ring attachment, experimental modifications were made in order to produce a reduction in temperature. These included the use of a moulded holder, a disc around the lamp neck inside the reflector, and a metal disc outside above the reflector. A substantial reduction in operating temperature resulted.

The modifications made upon larger fittings of this type again included the use of a disc close to the neck of the lamp and protruding outside the canopy of the reflector. In addition a number of longitudinal openings were cut into the canopy. Again a substantial reduction in temperature resulted. These apertures permitted free radiation from the lampholder, while the encircling discs baffled the heat stream around the lamp.

Typical office lighting fittings are dealt with in Tables III. and X. Satisfactory operating temperature results were obtained on one type only. Modifications made on some of the other patterns were on the same lines as those employed on the industrial fittings. As before, substantial reductions in the temperature rise resulted.

This single satisfactory office lighting fitting had been specially designed to produce low operating lead temperatures. The principles adopted to achieve this result were very much the same as those adopted in the modifications dealt with in the report, namely, the baffling of the heat stream around the lamp, the conduction of heat from the lampholder, and the use of a canopy of a type that permitted free radiation from the lampholder.

It is now possible to obtain heat-resisting rubber insulated flexible giving satisfactory operation at 65°C for a reasonable life (B.S.S. 7, 1938). It is shown that of the industrial fittings tested, none above 750 watts, in the range designed to meet the general problem, was able to comply with this condition at an ambient of 32.2°C. Of the office lighting fittings only one complied.

C. A. M.

* I.E.E. Journal 83, p. 518, and I.E.E. Regs. for Electrical Equipment of Buildings (11th Edition), p. 104.

Recommended Practice for Residential Fittings

A revised version of this treatise, issued by the Illuminating Engineering Society in the United States, has recently been made available. This embodies the result of much study by the Society's Committee on Residence Lighting. Following an initial discussion of the main features of domestic lighting types of fittings are divided into about a dozen main groups, ranging from direct to indirect and semi-indirect (60 per cent. or more light directed upward). Tabular data are presented showing the illumination that should be realised in average interiors from specified units and indicating the maximum brightness of the ceiling (½ to 1½ candles per sq. in.) and of the luminaire itself (up to 3 candles per sq. in. according to the zone considered).

Problems of Colour Mixing in the Dyeing Industry

By J. G. Grundy

(Summary of a paper read to the Colour Group of the Physical Society, at Bradford, on June 25)

In a lecture compiled to indicate to the physicist some of the difficulties confronting the practical dyer in the choice of dyestuffs for use in the dyeing of textiles and the problems of matching, it was explained, to avoid misunderstanding, that many of the terms used in the dyeing and textile industries have not necessarily the same meaning as when used by the physicist. For example, the term " shade " as used in the dyeing and textile industries is equivalent to the term " hue " as used by the physicist.

It is essential that people associated with the dyeing industry must be normal as far as colour sight is concerned. Normality of colour sight has for some time been tested and checked by the use of pseudo-isochromatic plates.

Different textiles are not all viewed in the same way when matching. Some patterns are viewed only by transmitted light, others by reflected light, whilst in some branches of industry both these and other factors have to be taken into consideration. Since matching shades is more relative than absolute, variations under different lighting conditions are experienced.

Attempts have been made in recent years to arrive at some defined standard of artificial illumination with a view to eliminating the difficulties which arise in matching patterns under the varying conditions of daylight. In spite of a large amount of work which has been carried out in this direction, daylight is still generally accepted, a good north light being taken for preference.

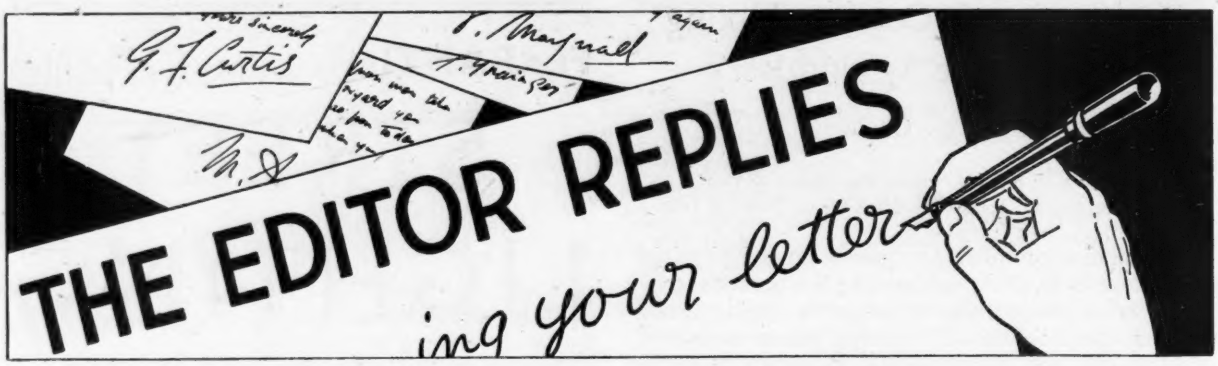
Matching to pattern in the textile trade is of high standard, but for practical reasons a certain amount of tolerance must be allowed, otherwise few dyehouses could be run for profit. A higher standard than normal vision for matching would not be practical.

The selection of a dye is not dependent upon shade only, but on the type of material to be dyed and the fastness properties required. Comparatively few dyestuffs yield a shade in the aqueous solution or a shade in the actual dyebath corresponding to the shade on the dyed material. Moreover, many dyes are insoluble in water and require special technique in the dyeing application; for example, vat, sulphur, and azoic dyes.

In combination shades of two or more dyestuffs it cannot be assumed that the dyes exhaust equally under different dyeing conditions, and this factor alone increases the difficulties in using some form of scientific instrument for measuring the amount of dye required. In a great number of cases it is not a single class of fibre that has to be dyed but a mixture of fibres. It is not uncommon in dyeings of this type to use six to eight different dyes on the union.

It does not appear possible to devise any type of scientific apparatus which could make due allowances for all the variables which occur in dyeing, and which could predict, with even reasonable accuracy, the percentage of dye or dyes to use for the production of a specific shade. These factors have to be predetermined by laboratory dyeing experiments, or gained by experience in large-scale practice. In view of the fact that the laboratory dyeing is carried out in the same way as large-scale practice, dyeing can be considered purely empirical.

If, by so means or other, a way can be devised to make the work of the dyer easier, more efficient, and effective, such a discovery will be more than welcome.



My remarks in last issue on **Specialised Textbooks** have brought some comments. I am reminded that in recent years the literature of this type contributed by the lighting industry has notably increased in value. A good instance is the deservedly popular E.D.A.—E.L.M.A. book on "Modern Factory Lighting," which deals in a very practical way with wartime problems. Mr. L. E. Buckell has brought to my notice a still more recent example, the booklet on "Electric Discharge Lamps," by V. J. Francis and H. G. Jenkins, issued by the General Electric Co., Ltd., last July. Of the sixty pages about a quarter deal with the physical phenomena underlying discharge lamps, the remainder with the chief features of specific types of Osira discharge and Osram fluorescent types. The book is excellently produced and illustrated, and affords an informative survey of the present position.

Some months ago I was remarking on the value of enterprise in the decoration of opaque hoardings used to replace **shattered windows.** Ingenuity in this direction is well repaid. Nothing is so destructive of interest, and therefore so detrimental to trade, as dull blank spaces. I have recently been reminded, however, of the great selling value of even a small window-space, enabling outsiders to see into the interior of the shop. In the case of one shop in a thriving provincial town, which had received a sudden "visitation," trade dropped almost to zero when opaque shutters replaced the window glass, even though the job was quite neatly executed. Only when the glass was partially restored did a recovery set in. Now that transparent substitutes for glass are becoming available it should always be possible to contrive some sort of window display.

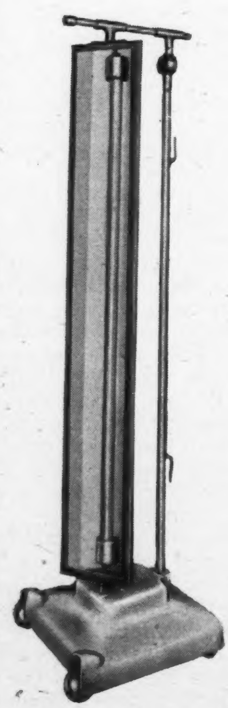
My attention has been drawn to further reports in the daily Press of ambitious schemes of **"night camouflage"** abroad, in particular the reported creation of an "Ersatz Berlin" several square miles in area. I have already expressed some scepticism in regard to the possibility of misleading aerial observers in regard to the position of a large city in this way, at any rate for any length of time, but no duobt much can be done to disguise the positions of certain features. Such expedients as the covering over of small areas of water or the hanging of green cloth over certain very distinctive streets might prove of some value. It has also been reported that main roads converging on Berlin have been painted with a dead-black substance in order to render them inconspicuous from above. Street lighting engineers, familiar with the polishing action of motor car wheels on tarred road surfaces, may well doubt whether the dead-black appearance would be preserved for very long.

According to the *Evening Standard* the belief that **negroes see better in the dark** than white men is supported by tests carried out by Dr. H. E. Sylva and Dr. W. M. Miles in North Carolina (U.S.A.). Negroes could identify a white card on a stick 100 feet away, and even identify its position (whether vertical or horizontal), when it could not be seen by the white men at all. Although the number of observers (seven white men and eight negroes) was not large, this definite conclusion is interesting. We should very much like to see some tests carried out by Dr. W. D. Wright with the "brillmeter," which he recently exhibited to the I.E.S.

I have been asked how to **light bookshelves.** At one time it was not unusual to find local lighting by tubular lamps mounted on racks along the tops of shelves, but my impression is that such local lighting is not worth while. It is difficult to achieve anything approaching even illumination—nor does this help a great deal when the effect of the angle at which books on the lower shelves is considered. When shelves are arranged in alcoves fairly even illumination on the faces of the books can be achieved by a suitably placed central light, but there is the drawback that shadows of the observer's body are apt to be cast on the books. The fact that titles of books are so often executed in gold, and that the materials used for binding are frequently glossy, is also of moment. Glittering reflections of sources of light are apt to interfere with the reading of small type. (I have known cases in which it was actually easier to read the titles if one stood "in one's own light" so that no direct light from the central source fell on the bookshelf.) Taking all things into consideration I have very little doubt that the best method of lighting shelves is to rely on indirect illumination. The shadow difficulty is thus avoided, and the effect of glitter eliminated, and it is easy to secure even illumination of shelves from top to bottom without having to be too particular about the position of the light-source.

Portable Fluorescent Lighting Equipment

The fluorescent tubular lamp has doubtless been the outstanding lighting development of the war. In its present standardised form it is being already widely used in industry, but there will be many modifications in design and many other applications in time to come.



One evident difficulty in connection with the new lamps has been that the demand tends to outrun the supply. When it is possible to flood the entire room with light from these lamps we have doubtless the ideal condition, but in some cases users must be content with a few lamps, furnishing an equivalent to diffused daylight at certain important points.

In such circumstances the Ediswan "Portolux" unit should meet a need. The standard 5 ft. 80-watt tube is fitted into a reflector trough of sheet steel, carried in a tubular steel frame. This frame is mounted on a heavy cast iron base, which provides housing for the choke, condenser, and other control equipment. The device is thus self-contained and can be connected to a 3-core supply cable and quickly wheeled into position. We are indebted to *Signs* for the accompanying illustration.

Literature on Lighting

(Abstracts of Recent Articles on Illumination and Photometry in the Technical Press)

(Continued from page 104, July, 1941)

II.—PHOTOMETRY

168. Spectrophotometer.
Anon. Review of Scientific Instruments, Vol. 12, No. 5, May, 1941.
A double monochromator spectrophotometer is described, the instrument consisting of two units. The light source is a line filament which is rendered essentially monochromatic. This light then passes through the absorption cell to a photocell. The photo cell current produces a potential across a resistance, and by means of the second unit, which is an electrometer, this potential is measured by potentiometric means. The instrument can be used for colorimetric work, and to determine transmission factors. W. E. H.

III.—SOURCES OF LIGHT

169. Making Light for To-morrow.
Anon. Elect., 127, pp. 3-4, July 4, 1941.
A summary is given of progress in America during the last two years in the development of various light sources. C. A. M.

170. Vapour Discharge Lamps.
J. P. Wolfenden. Elect., 127, pp. 31-32, July 18, 1941.
A comparison is made between the various types of electric discharge lamps now available. Operating mechanisms are described, together with circuit diagrams, starting characteristic curves, spectral data, and oscillograms. C. A. M.

171. Guide to 50 ft.c. Fluorescent Lighting.
Anon. El. World, 115, p. 1,342, April 19, 1941.
A schedule has been prepared based on the more usual forms of lighting fittings designed for use with tubular fluorescent lamps, from which the number of units required to provide 50 ft.c. in any normal installation may be calculated. S. S. B.

172. Performance of Tubular Fluorescent Lamps in Service.
C. E. Weitz, L. R. Keiffer, C. L. Amick. Magazine of Light X., No. 3, pp. 17, 33-39, April, 1941.
A detailed study is given of operating conditions of fluorescent lamps, giving attention to faults that may develop, and the necessary action to be taken. C. A. M.

173. Cutting Interference from Fluorescents.
A. C. Hoyle. El. World, 115, p. 1.344, April 19, 1941.
Recommendations are given for reducing radio interference from tubular fluorescent lamps. S. S. B.

174. "Sterilamp" Used in Air Conditioning.
Anon. El. World, 115, p. 1,860, May 31, 1941.
A report is given of extensive tests on the use of "sterilamp" u.v. lamps in air-conditioning plant. Recommendations for maximum effectiveness in destroying bacteria are made. S. S. B.

IV.—LIGHTING EQUIPMENT

175. Burner Control.
Anon. El. World, 115, p. 1,023, March 22, 1941.
An unusual type of light actuated mercury switch is described, for use in conjunction with safety control panels for oil burners, etc. The light from the flame is concentrated on to a sensitive bimetal strip, which closes the circuit by movement of one arm into a pool of mercury. No photosensitive material is used, the operation depending on the heating of the strip. S. S. B.

V.—APPLICATIONS OF LIGHT

176. Progress in Engineering Knowledge in 1940.
P. L. Alger. G.E. Review, Vol. 44, No. 2, February, 1941.
Under various sub-titles the author discusses laboratory experiments on the visibility of type with practical tests carried out in schools; developments in carbon and high pressure mercury vapour arcs; street and tunnel lighting and watercooled mercury vapour lamps H. J. T.

177. University Lighting.
G. E. Walter. Magazine of Light, X., No. 3, pp. 18-21. April, 1941.
Results of a survey of illumination values in Iowa State College are briefly summarised. It is recommended, in order to reduce excessive contrast, that room illumination values should not be less than 20 per cent. of the values on the desk. C. A. M.

178. Lighting of School.
Anon. Elect., 126, p. 330, June 6, 1941.
Details are given of recent school lighting installations in Lancashire. C. A. M.

179. Office Lighting.
W. G. Darley. Magazine of Light, X., No. 3, pp. 8-12. April, 1941.
The lighting equipment of two office buildings is described. Fluorescent tubular lamps are recessed into the ceilings, and give illumination values ranging between 40 and 50 ft.c. C. A. M.

180. The Re-lighting of Factories.
Anon. The Electrical Times, Vol. 100, No. 2,596, July 24, 1941.
The importance of adequate lighting in all factories engaged on war-work is stressed. A brief summary is given of new schemes already carried out, and supply difficulties are discussed. W. E. H.

181. Programmed Light for Machinery Plant.
J. V. Dempsey. El. World, 115, p. 1,016, March 22, 1941.
The lighting of an American factory has been completely overhauled and brought up to date. Details of the lighting schemes adopted in different sections are given. Illumination values of 25-35 ft.c. are provided. S. S. B.

182. Drying Lamp Installation.
R. E. Lagerstrom. Magazine of Light, X., No. 3, pp. 13 and 27, April, 1941.
Equipment for the drying of a finish coating for insulation board is described. C. A. M.

183. Infra-Red Trebles Production Rate.
Anon. El. World, 115, p. 1,671, May 17, 1941.
Details are given of an installation of infra-red drying lamps at an American factory. The output of certain articles has been trebled, and of others increased more than eight times. S. S. B.

184. Sixty Ft.c. for Jewellery Store.
Anon. El. World, 115, p. 1,017, March 22, 1941.
Effective use has been made of down light from flush-type louvred fixtures in the ceiling, directly over jewellery display cases and in wall cases. Details of the installation are given. S. S. B.

185. Fluorescent Lighting in Colours.
R. J. Seitz. Magazine of Light, X., No. 3, pp. 22-23, 27, April, 1941.
Details are given of two floodlighting installations using tubular fluorescent lamps. C. A. M.

186. Fluorescent Lighting Aids Merchandising.
W. T. Eby. Magazine of Light, X., No. 3, pp. 14-17, April, 1941.
New methods in the use of tubular fluorescent lamps in the display of goods are described. One is the use of lamps vertically around pillars. Another is their use in a continuous run along cornices. C. A. M.

187. Fluorescent Lamps for Phoenix Printery.
T. F. McDonough. El. World., 115, p. 1,350, April 19, 1941.
The author describes an installation of fluorescent tubular lamps in a printing shop. In addition to increased illumination, an advantage has been found in the reduction of radiated heat. S. S. B.

188. Sodium Lighting, New York State Barge Canal.

F. R. Lindsey. G.E. Review, Vol. 44, No. 2, Feb., 1941.

Describes a sodium lighting unit applied for use on an inland waterway. H. J. T.

189. High Lights and Side Lights.

Guy Bartlett and Phillips C. Caldwell. G.E. Review, Vol. 44, No. 2, February, 1941.

Describes a proposed method of indirect lighting for vehicle tunnels, giving freedom from glare and easy maintenance. A photograph of a model scale experiment is shown. H. J. T.

VI.—MISCELLANEOUS

190. Colour.

Dr. Bruno Schweig. "Glass," Vol. 18, No. 7, July, 1941.

The article gives a general review of colour phenomena including its definition, objective, and subjective meanings, and the relationship between colour and chemical constitution for both organic and inorganic substances. W. E. H.

191. Anti-Reflection Films on Glass.

A. F. Turner. The Glass Industry, Vol. 22, No. 6, June, 1941.

The application of solid films to the surfaces of glass lenses results in a decrease of reflection losses and an absence of "ghost" images. The present article gives a theoretical treatment of this process. W. E. H.

192. Discolouration of Quartz Windows of an Ultra-Violet Source.

R. J. Dwyer and *H. W. Leighton.* Review of Scientific Instruments, Vol. 12, No. 3, March, 1941.

It has been found that the quartz window of a hydrogen discharge tube became markedly discoloured after a period of use extending over several months. It is recommended that such windows should be readily replaceable. W. E. H.

193. Electronic Photometer for Vitamin A.

Anon. Review of Scientific Instruments, Vol. 12, No. 2, March, 1941.

This instrument operates upon the principle that the absorption of ultra-violet radiation by a Vitamin A solution is a measure of the Vitamin A concentration. A photoelectric cell and electronic amplifier are used, and the source of ultra-violet radiation is an argon glow lamp and special filter. W. E. H.

194. Ophthalmograph.

Anon. Review of Scientific Instruments, Vol. 12, No. 4, April, 1941.

This instrument records graphically on a photographic film eye movements during reading. It reveals speed of reading, span of word recognition, eye co-ordination and eye habits associated with psychological reactions.

Small lights focussed on the eyes are reflected on the corneas and, magnified four times, appear as tiny beads of light in the camera reflex finder. The movement of the light beads correspond with the movements of the eyes. W. E. H.

195. Eikonometer.

Anon. Review of Scientific Instruments, Vol. 12, No. 5, May, 1941.

This instrument has been developed to measure aniseikonia, a recently discovered eye condition, in which the ocular images received by the brain from the two eyes are unequal in either size or shape, or both. This defect of vision may affect stereoscopic vision, and objects in space may appear tilted, rotated, and distorted. This instrument enables correcting lenses to be prescribed. W. E. H

196. Precision Refractometers.

Anon Review of Scientific Instruments, Vol. 12, No. 3, March, 1941.

A range of precision refractometers covering a wide refractive index range are described. The prism system is mounted vertically upon a long taper bearing, and a sodium vapour lamp is provided. W. E. H.

197. The Polarising Properties of Dyed Cellophane Films.

S. Silverman. Review of Scientific Instruments. Vol. 12, No. 4, April, 1941.

A brief description of the polarising properties of some dyed cellophane sheets is given. It has been found that certain dyes only exhibit polarisation phenomena. W. E. H.

198. Silver Coatings on Non-Metallic Surfaces.

Anon. The Chemical Age, Vol. XLV., No. 1,151, July, 1941.

Practical methods of depositing silver on plastic surfaces are given. Good results have been obtained with three methods of immersion silvering. Although the adhesion of the silver deposits to a non-metallic surface are not as high as to a basis metal, it is often quite strong. W. E. H.

199. An Optical Slit.

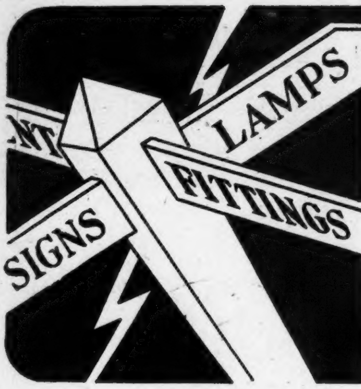
J. Strong. Review of Scientific Instruments, Vol. 12, No. 4, April, 1941.

A form of "parallelogram" optical slit is described in which the slit opening changes slowly when nearly closed and rapidly when it is nearly open. This reversal of the usual relationship is of great use in many instruments. W. E. H.

200. An Improved Optical Lever.

P. W. Crist. Review of Scientific Instruments, Vol. 12, No. 4, April, 1941.

It is possible to increase the angular rotation of the beam of light reflected by an "optical lever" by causing repeated reflections from the moving mirror. In the system under review this multiple reflection is obtained by mounting a second mirror parallel to, and facing, the first mirror. W. E. H.



WHERE TO BUY

We invite applications for spaces in this new section of the journal. Particulars of terms for each space (approx. 1 inch deep and 3½ inches wide) are given below.

These terms are equivalent to half our ordinary advertising rates, but not less than 12 successive monthly insertions can be accepted on this basis, and amounts are payable in advance.

Payment for an advertisement in this section entitles the advertiser to receive *Light and Lighting* during the period of the contract.

Terms:	12 Successive Monthly Insertions	£3 10 0	Payable in Advance
	24 " " "	£6 0 0	
	36 " " "	£8 10 0	

A DIRECTORY OF LIGHTING EQUIPMENT

INDEX TO "WHERE TO BUY"

N.B.—The numbers are those attached to individual entries in the Directory *(See pp. 123—124)*

"Artlite" Specialities

A display of "Artlite" equipment for display lighting, etc., due to the ingenuity of Paymaster Captain Robert R. Hoare, R.N., is on view at the premises of Messrs. Dernier and Hamlin, Ltd. (Newman-street, London, W.1). The devices include Captain Hoare's special system of lighting pictures and posters, reflectors for tubular lamps, both of the fixed-focus and adjustable variety, and apparatus for picture-projection for advertising purposes. Although outdoor advertising is so greatly restricted by present conditions, stress is laid on post-war possibilities. It should also be recalled that in certain positions under cover (in railway stations, for instance) there are still opportunites for effective display.